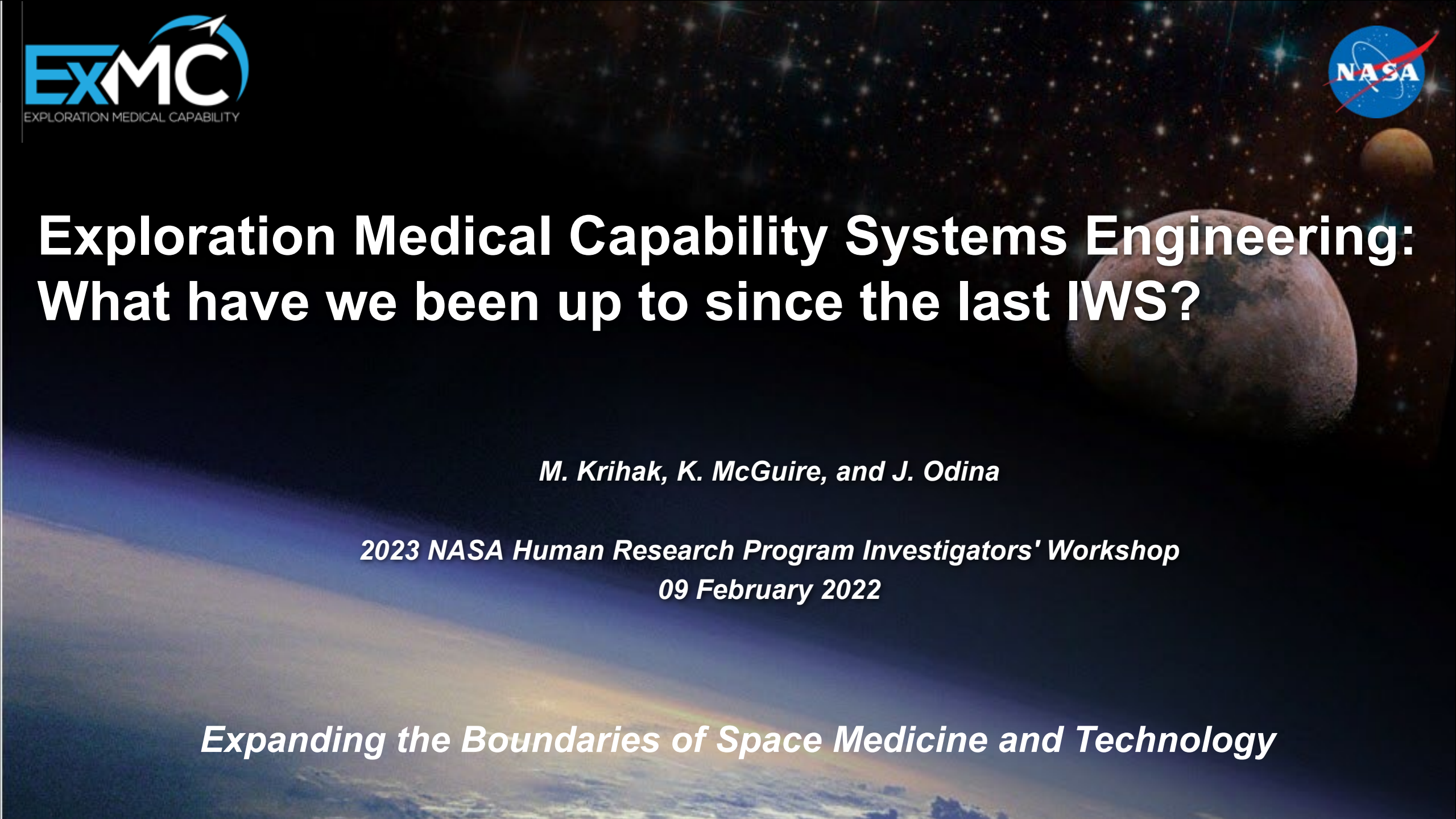


Exploration Medical Capability Systems Engineering: What have we been up to since the last IWS?

M. Krihak, K. McGuire, and J. Odina

2023 NASA Human Research Program Investigators' Workshop
09 February 2022

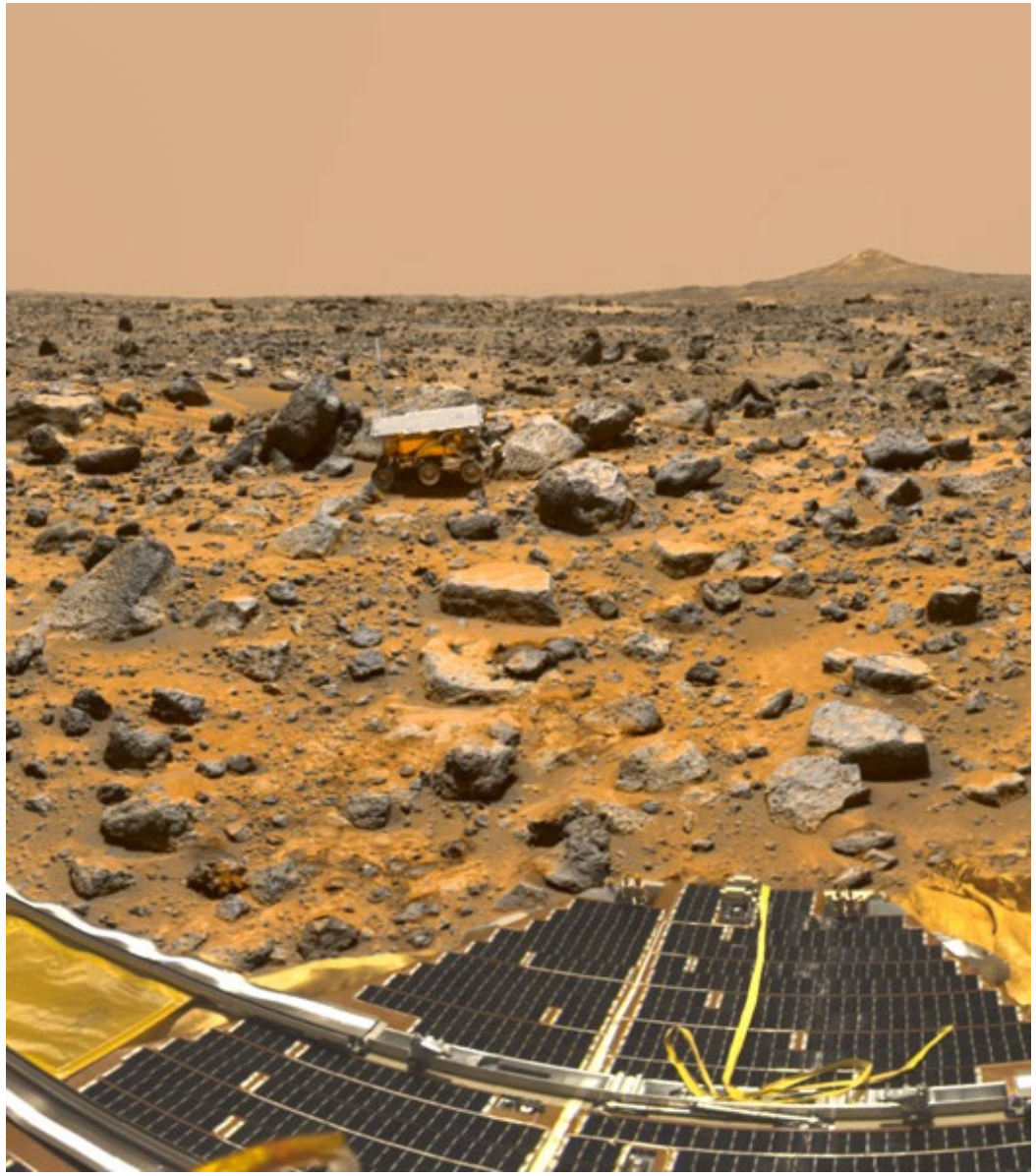
Expanding the Boundaries of Space Medicine and Technology

ExMC and Exploration Challenges

Challenges of Exploration:

- Resource constraints (e.g., mass, volume, power, data, etc.)
- Little to no resupply or evacuation
- Communications delays and disruptions
- Unknown effects on crew health and performance
- Potential limited knowledge, skills and ability (KSA)
- Skills erosion over time
- Increased crew autonomy

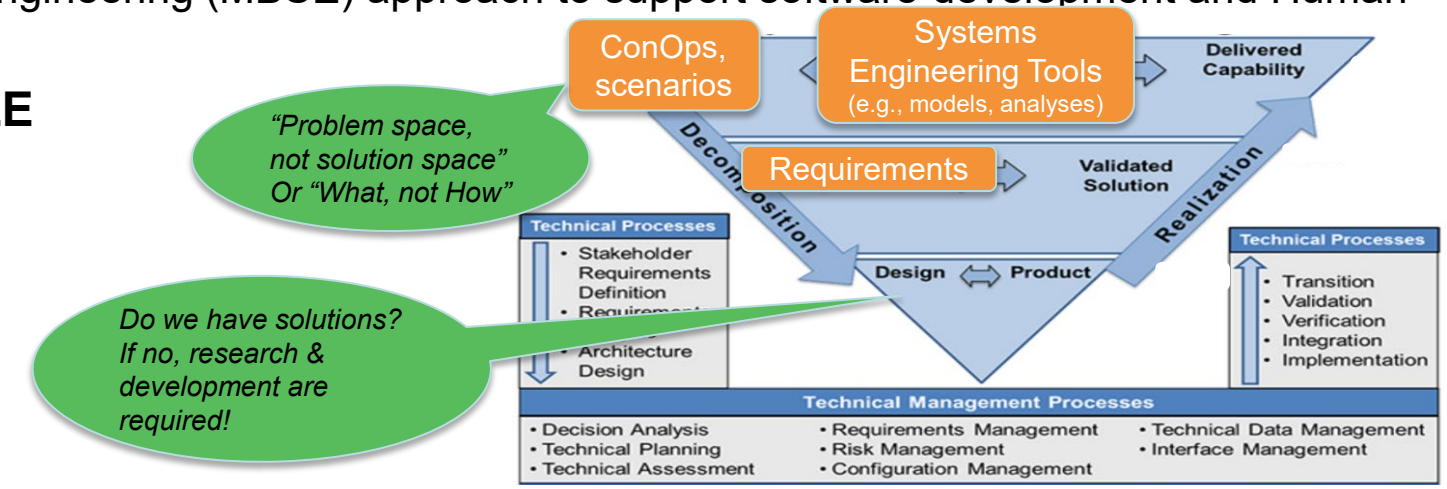
The Human Research Program (HRP) Exploration Medical Capability Element (ExMC) uses a Systems Engineering (SE) approach to understand the needs and challenges of exploration medical systems.



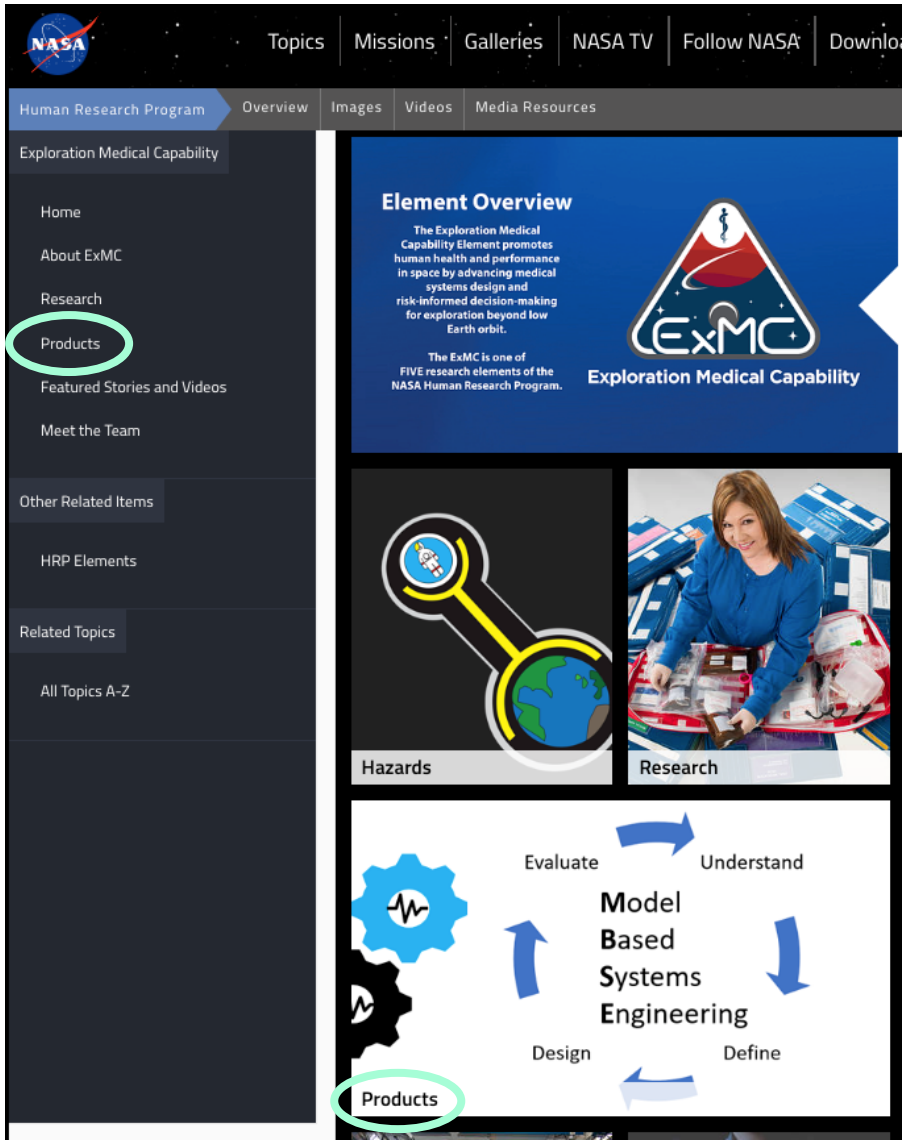
https://solarsystem.nasa.gov/planets/mars/overview/

Highlights Since IWS 2022

- **Medical System Foundation for Level of Care IV: <u>Short-Duration</u> Lunar Orbit**
  - Updates to the ExMC public-facing website
- **<u>Long-Duration</u> Lunar Orbit and Lunar Surface (LDLOLS) Medical System Foundation**
  - Concept of Operations (ConOps) baseline
  - Medical System Requirements
  - Traces of capabilities to medical system requirements
  - *Updated ConOps and requirement traces to the NASA Spaceflight Human-System Standards [NASA-STD-3001 (Volumes 1, Rev. B and 2, Rev. C)] coming in FY23*
- **Support for the Informing Mission Planning via Analysis of Complex Tradespaces (IMPACT) Project**
  - Developed the LDLOLS mapping file (traces of medical capabilities to medical requirements)
  - Medical Database model-based systems engineering (MBSE) approach to support software development and Human Centered Design (HCD) strategies
- **Adopted new Tools: JIRA and CRADLE**



Medical System Foundation for Level of Care IV: Short-Duration Lunar Orbit Model



https://www.nasa.gov/hrp/elements/exmc/products

ExMC Products

Publicly available!!!

The Medical System Foundation for Level of Care IV: Short-Duration Lunar Orbit Model

What is the purpose of this system model?

NASA's Human Research Program includes the Exploration Medical Capability (ExMC) element. This element promotes human health and performance in space by advancing medical systems design and risk-informed decision-making for exploration beyond low-Earth orbit.

ExMC's Medical System Foundation for Level of Care IV: Short-Duration Lunar Orbit model is a set of information for a Gateway-like mission of 42 days or less. It consists of a Concept of Operations (ConOps), an Accepted Medical Condition List (AMCL), and a system model which includes medical requirements. We call it a "foundation" because it is intended to be a starting point for missions with similar profiles. We expect someone will be able to take this foundation and tailor it for their own use by customizing the ConOps, changing some of the AMCL, or modifying other functional requirements to suit a particular mission profile.

How do I view the system model?

To access the system model, click on the link below. Some content (such as tables) may take a few seconds to load because of the amount of information being displayed.

Medical System Foundation for Level of Care IV: Short-Duration Lunar Orbit ← **Link to the model**

What resources can guide me through this model?

This video provides a high-level overview of the purpose of the Medical System Foundation and its content.

Medical System Foundation: Overview

This video walks you through how to navigate the content within the Medical System Foundation Model.

Medical System Foundation: Navigation

This video explains how to navigate scenarios and functions within the Medical System Foundation Model. It also explains the purpose of the model's scenarios and functions.

Medical System Foundation: Scenarios and Functions

Links to videos

LDLOLS Medical System Foundation

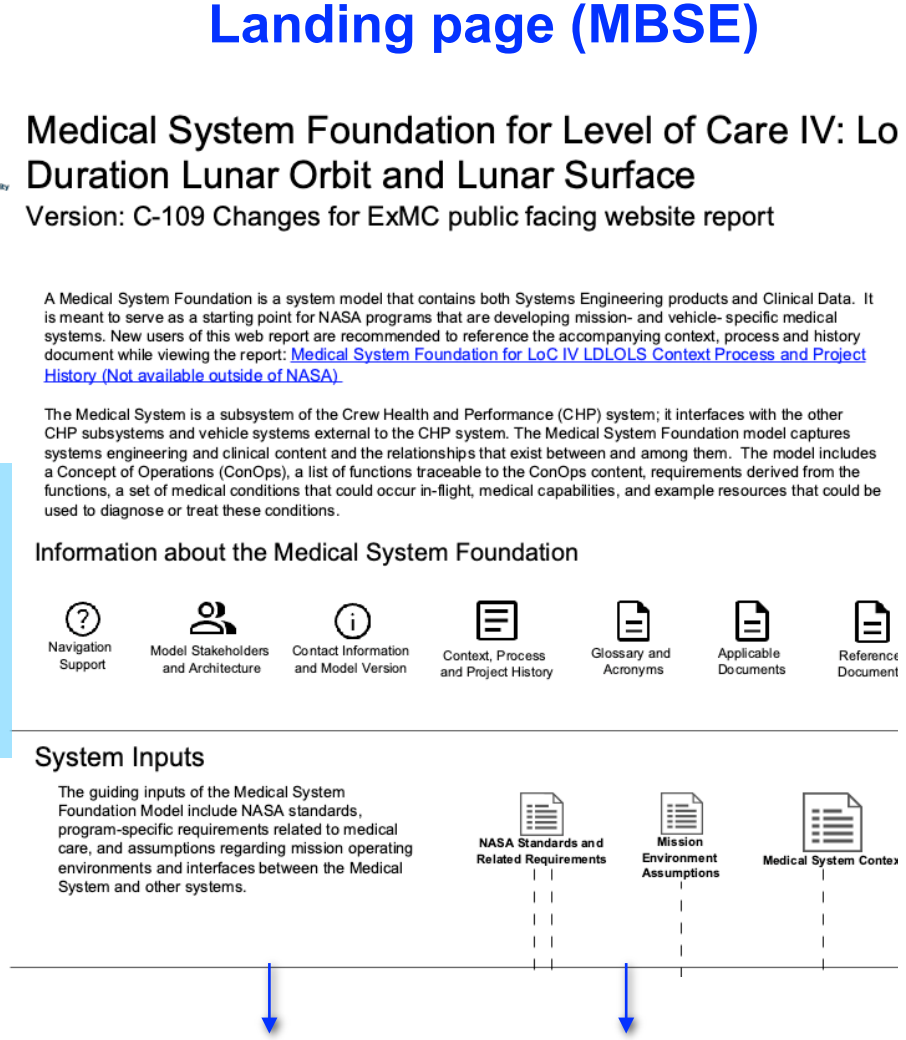
LDLOLS Medical System Foundation -

- Baseline approved in 2022 by ExMC Control Board

Sarah Arai will present:

‘Medical System Foundation Overview for Long-Duration Lunar Orbit and Surface Operations Missions’

Landing page (MBSE)



Medical System Foundation for Level of Care IV: Lo
Duration Lunar Orbit and Lunar Surface
Version: C-109 Changes for ExMC public facing website report

A Medical System Foundation is a system model that contains both Systems Engineering products and Clinical Data. It is meant to serve as a starting point for NASA programs that are developing mission- and vehicle- specific medical systems. New users of this web report are recommended to reference the accompanying context, process and history document while viewing the report: Medical System Foundation for LoC IV LDLOLS Context Process and Project History (Not available outside of NASA)

The Medical System is a subsystem of the Crew Health and Performance (CHP) system; it interfaces with the other CHP subsystems and vehicle systems external to the CHP system. The Medical System Foundation model captures systems engineering and clinical content and the relationships that exist between and among them. The model includes a Concept of Operations (ConOps), a list of functions traceable to the ConOps content, requirements derived from the functions, a set of medical conditions that could occur in-flight, medical capabilities, and example resources that could be used to diagnose or treat these conditions.

Information about the Medical System Foundation

Navigation Support | Model Stakeholders and Architecture | Contact Information and Model Version | Context, Process and Project History | Glossary and Acronyms | Applicable Documents | Reference Document

System Inputs

The guiding inputs of the Medical System Foundation Model include NASA standards, program-specific requirements related to medical care, and assumptions regarding mission operating environments and interfaces between the Medical System and other systems.

NASA Standards and Related Requirements | Mission Environment Assumptions | Medical System Contex

(Scrolling down)

Concept of Operations and Functional Decomposition

The Medical System Foundation systems engineering content consists of a Concept of Operations (ConOps) and System functions.

The ConOps includes stakeholder needs, system goals, mission constraints, operating environments, and representative scenarios that highlight potential needs the system must fulfill.

System functions and subfunctions are derived from the ConOps via a functional decomposition process. These functions served as an input to the requirements development process.

Concept of Operations | Functional Decomposition

Clinical Content

The Medical System Foundation clinical content includes medical conditions and the derived clinical capabilities and associated resources needed to diagnose and treat those medical conditions. The clinical capabilities served as an input to the technical requirements derivation process. These contents as well as the traceable relationships between them live in this section.

Medical Conditions | Clinical Capabilities | Medical Resources

Technical Requirements

The Medical System requirements represent the functional and non-functional System needs and are driven by the content documented in the ConOps (e.g., scenarios and functions), clinical capabilities, NASA standards and historical documents, and parent system requirements. Interface requirements were also developed, which represent medical needs that are allocated to other systems based on the proposed system architecture. The Medical System functional, non-functional, and interface requirements are defined within NASA as Level 4 and have traces to their Level 2 and 3 parent requirements, NASA Standards and historical documents, and the clinical capabilities.

Candidate Test Objectives | Technical Requirements

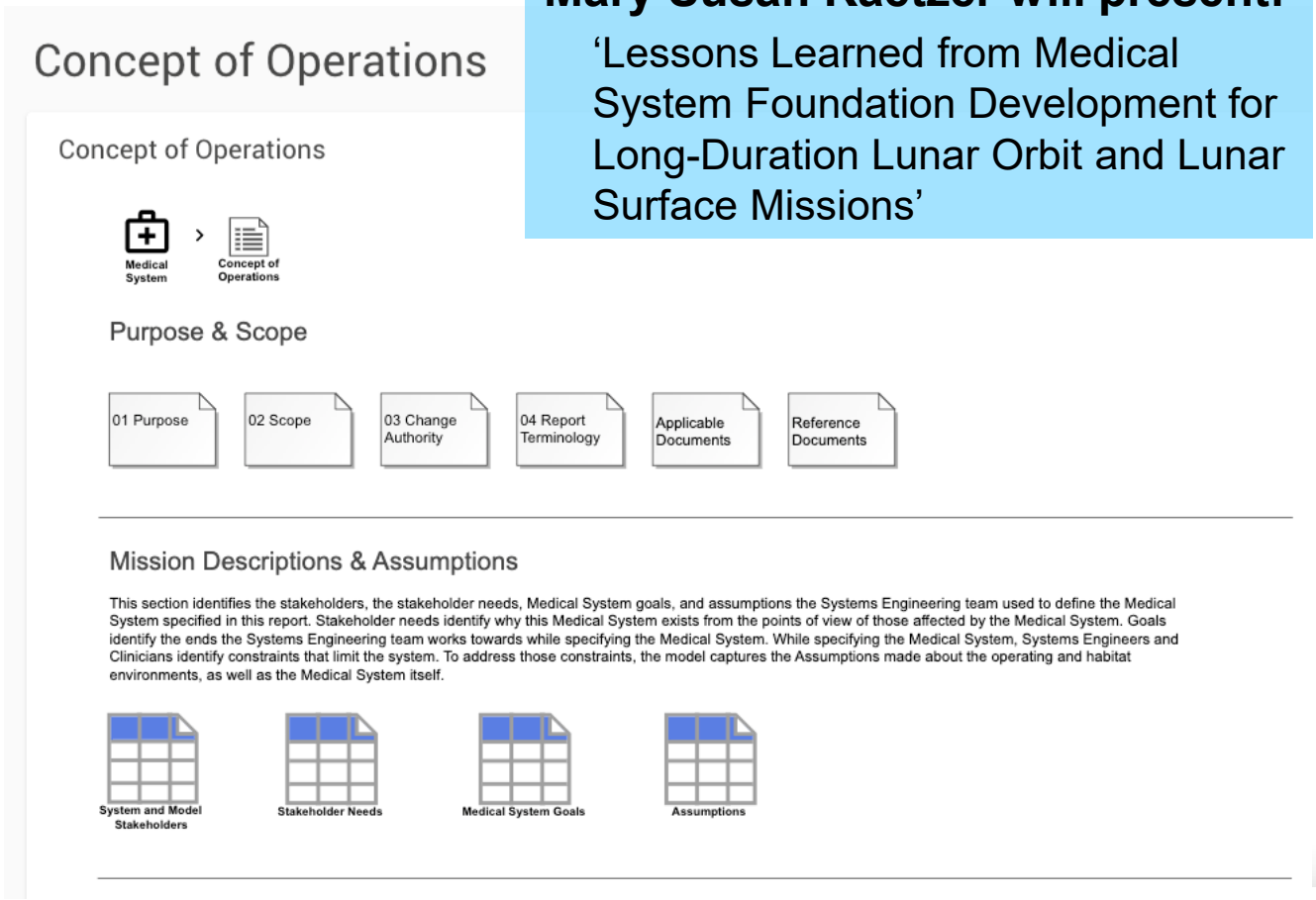
Coming soon in 2023: LDLOLS Medical System Foundation on the ExMC website

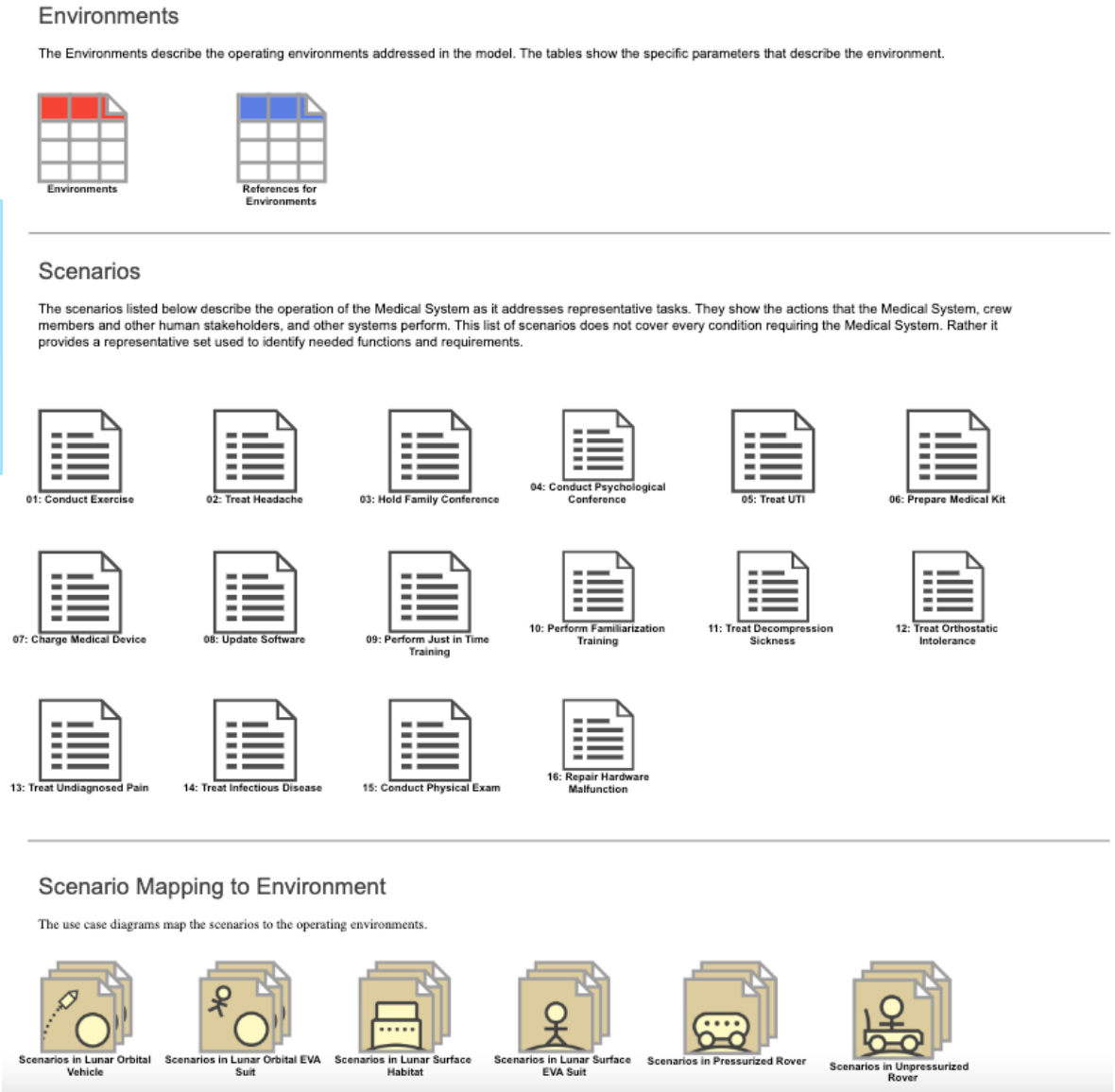
LDLOLS Medical System ConOps

LDLOLS Medical System Foundation ConOps baseline approved in 2022

Mary Susan Kaetzer will present:

‘Lessons Learned from Medical System Foundation Development for Long-Duration Lunar Orbit and Lunar Surface Missions’



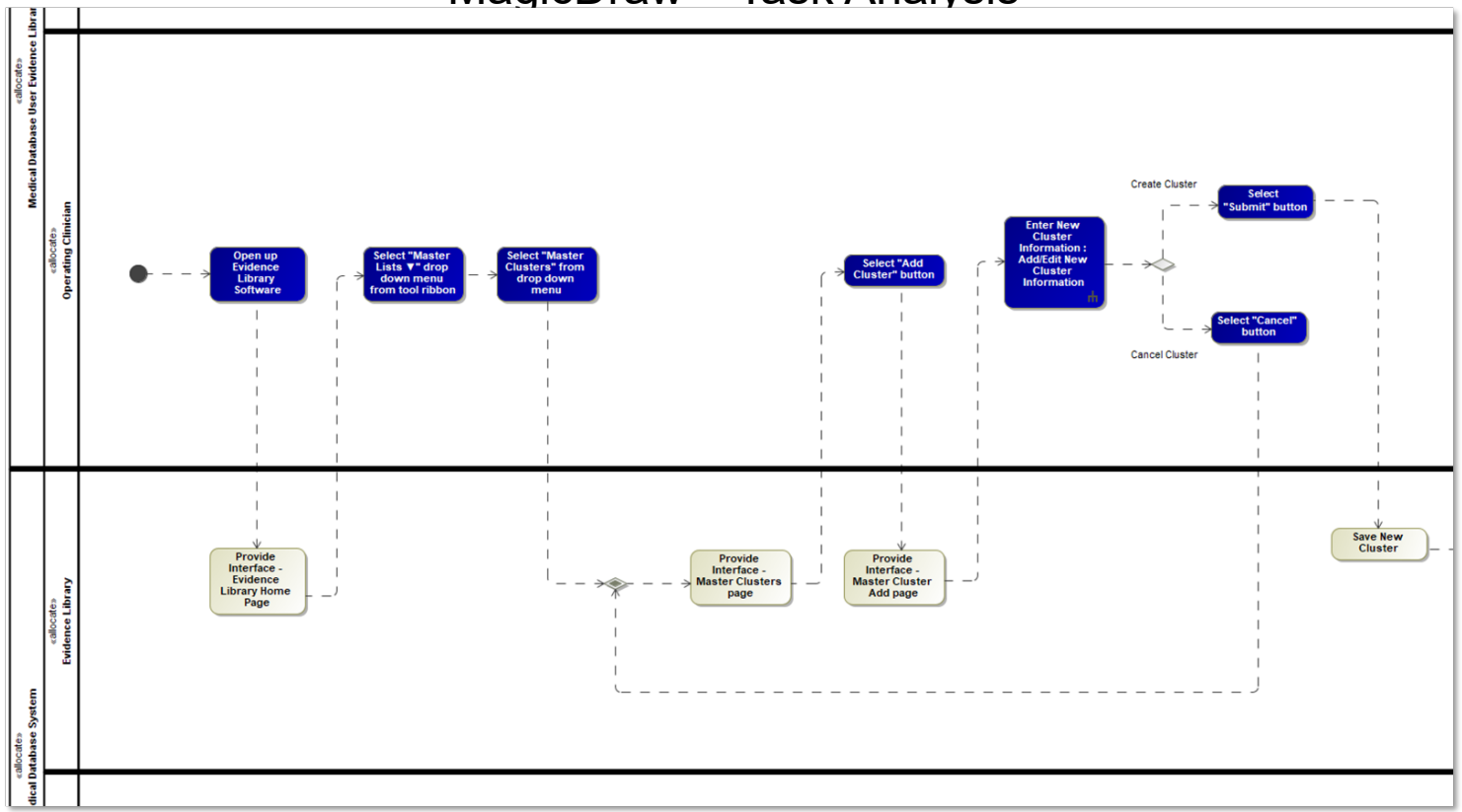


MBSE Support of Medical Database/IMPACT Project

Later this session Tyler Duke will present:

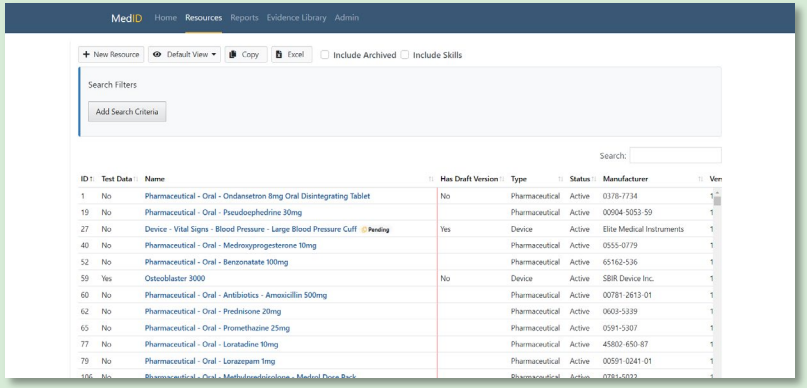
'Analysis of the Value Added When Deploying a Model-Based Approach for the Validation and Verification of the Medical Database Software'

MagicDraw – Task Analysis

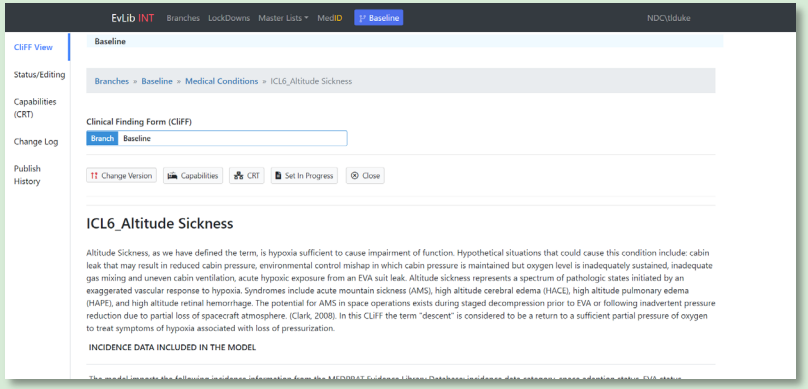


MEDICAL DATABASE

MedID



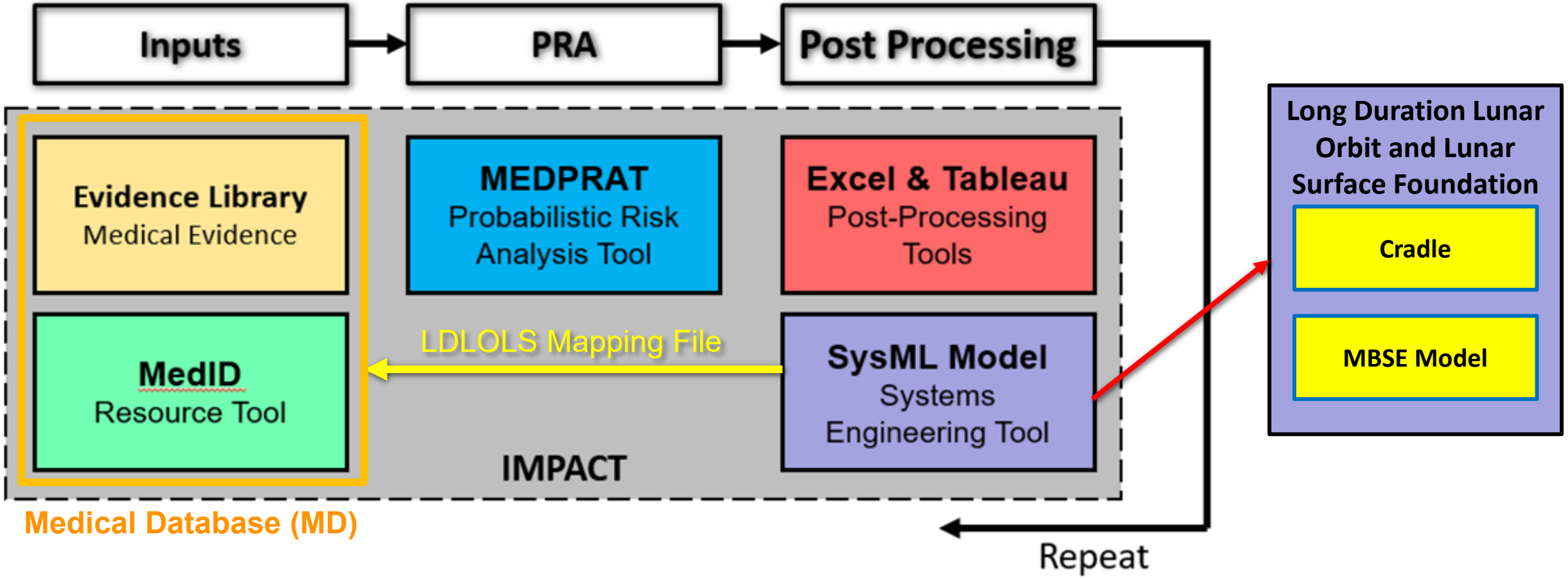
Evidence Library



LDLOLS and IMPACT

LDLOLS foundation provides the mapping file

- Traces of medical capabilities to medical requirements



Cradle to MagicDraw Synchronization

Cradle

- Adopted by ExMC Systems Engineering (SE) in FY22 as our requirements management software tool
- Used to load, create, inter-link and publish information for all stages in a systems engineering project
- Acts as our source of truth for requirements

Requirements maintained in Cradle

Query: CHP-REQ-L4 - All

Start Page | CHP-REQ-L4 - All

	System	Type	Order	Category	Subcategory	Identity	Name	Text	Rationale	Comment
333	Task Performance Support	Functional	45	Task Management	Procedure Support	L4-Lunar-TaskSys-0060	Support sensorimotor testing procedures	The Habitat CHP Task Performance Support System shall support sensorimotor testing procedures.	The Habitat CHP Task Performance Support System needs to support sensorimotor testing procedures. Changes in gravitational pull (e.g., going from 1g to microgravity) can cause changes in astronaut's balance, locomotion, eye-hand coordination, visual	
334	Task Performance Support	Functional	46	Task Management	Procedure Support	L4-Lunar-TaskSys-0061	Support cognitive testing procedures	The Habitat CHP Task Performance Support System shall support cognitive testing procedures.	The Habitat CHP Task Performance Support System needs to support cognitive testing procedures. Space flight stressors can cause changes in an astronaut's attention, memory, decision-making, problem-solving, logical reasoning, and spatial cognition, applied in both	
335	Task Performance Support	Functional	47	Task Management	Procedure Support	L4-Lunar-TaskSys-0062	Support behavioral health assessment	The Habitat CHP Task Performance Support System shall support behavioral health assessment.	The Habitat CHP Task Performance Support System needs to support assessments of the crew's behavioral health. Behavioral health focuses on the astronaut' habits and their impact on physical and mental health. Factors that can affect the behavioral health of the	
336	Task Performance Support	Functional	48	Task Management	Procedure Support	L4-Lunar-TaskSys-0063	Support personal protection procedures	The Habitat CHP Task Performance Support System shall support personal protective equipment procedures.	The Habitat CHP Task Performance Support System needs to support personal protective equipment (PPE) procedures. This capability includes how to don and doff equipment. PPE in healthcare includes gloves,	
337	Task Performance Support	Functional	49	Task Management	Procedure Support	L4-Lunar-TaskSys-0064	Support evacuation procedures	The Habitat CHP Task Performance Support System shall support emergency evacuation procedures.	The Habitat CHP Task Performance Support System needs to support emergency evacuation procedures in the case of critical illness or injury. Medical conditions of varying complexity, severity, and emergency will	
338	Task Performance Support	Functional	50	Task Management	Procedure Support	L4-Lunar-TaskSys-0065	Support end-of-life care procedures	The Habitat CHP Task Performance Support System shall support end-of-life care procedures.	The Habitat CHP Task Performance Support System needs to support end-of-life care procedures. Palliative care in end-of-life procedures aim to help if a crewmember has a life-limiting or life-threatening illness or accident. The focus of this type of care is	
339	Task Performance Support	Functional	51	Task Management	Procedure Support	L4-Lunar-TaskSys-0066	Support medical habitat assembly	The Habitat CHP Task Performance Support System shall support medical habitat assembly on the lunar surface.	The Habitat CHP Task Performance Support System needs to support the assembly of a medical habitat in space orbit and on surface. Construction will take place in reduced gravity, significant dust and radiation. Types of medical habitat assembly support are specified at Level 5.	
340	Task Performance Support	Functional	53	Task Management	Procedure Support	L4-Lunar-TaskSys-0067	Support medical equipment repair procedures	The Habitat CHP Task Performance Support System shall support medical equipment repair procedures.	The Habitat CHP Task Performance Support System needs to support medical equipment repair procedures. Delays in repair can be dangerous and broken machines can delay diagnosis. Methods to support repair procedures are specified at Level 5.	
341	Task Performance Support	Functional	55	Task Management	Team Coordination	L4-Lunar-TaskSys-0068	Support crew-ground information exchange	The Habitat CHP Task Performance Support System shall support crew-ground information exchange.	The Habitat CHP Task Performance Support System needs to support information exchange between the crew and ground. This capability supports situation awareness (e.g., comparable information on displays, available inventory) by pushing information	
342	Task Performance Support	Functional	56	Task Management	Team Coordination	L4-Lunar-TaskSys-0069	Provide communication receipt confirmation	The Habitat CHP Task Performance Support System shall provide communication receipt confirmation.	The Habitat CHP Task Performance Support System needs to provide rapid confirmation that communication is received. Acknowledgment needs to re-assure the sender on transmission reception, that the	
343	Task Performance Support	Functional	57	Task Management	Team Coordination	L4-Lunar-TaskSys-0070	Support crew-automation information exchange	The Habitat CHP Task Performance Support System shall support crew-automation information exchange.	The Habitat CHP Task Performance Support System needs to provide information exchange capabilities between the crew and automation (e.g., decision support, environmental systems). Automation refers to	
344	Task Performance	Functional	58	Task Management	Team Coordination	L4-Lunar-TaskSys-0071	Support crew-robot information	The Habitat CHP Task Performance Support System	The Habitat CHP Task Performance Support System	

Export

Requirements within MagicDraw

Medical System Functiona... [Read-Only]

Add New | Add Nested | Add Existing... | Delete | Remove From Table | Unnest | Nest | Columns | Export | Report

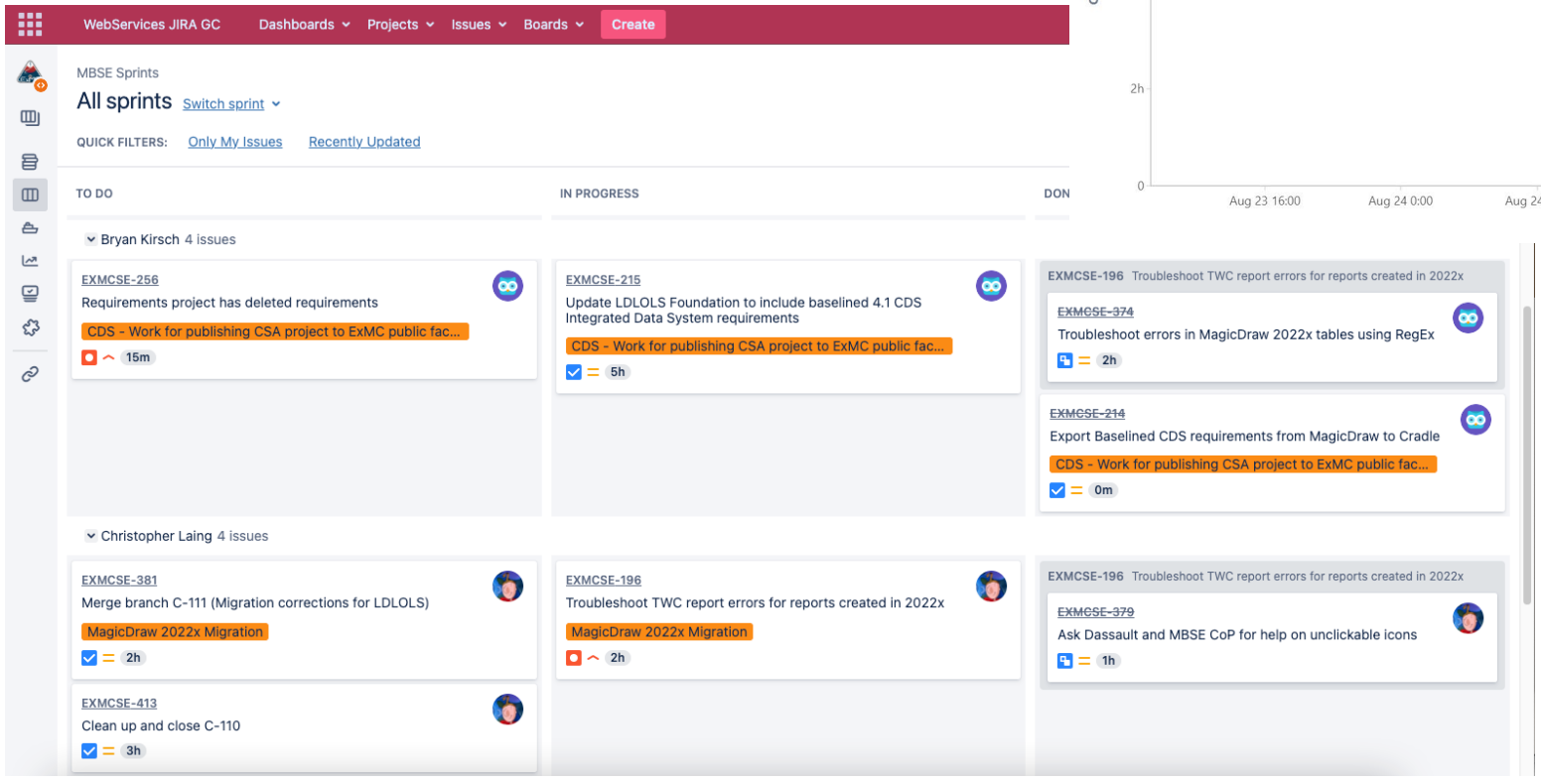
Criteria

Scope (optional): Medical System Requirements | Filter: | Context (optional):

#	Requirement ID	Requirement Name	Requirement Text	Requirement Rationale
1	L4-Lunar-MedSys-0002	Provide crew physical access to medical inventory	The Habitat CHP Medical System shall enable crewmembers physical access to medical inventory.	The Habitat CHP Medical System needs to enable crew access to inventory. This requirement focuses on providing the crew physical access to inventory as a complement to information accessed through medical records. Physical access to inventory for the medical system is necessary to support diagnostic and surveillance laboratory activities.. This includes tracking quantities and dosages of dispensed inventory, such as medications, and providing adequate stowage for different medications (cold versus ambient temperature).
2	L4-Lunar-MedSys-0003	Prepare habitat for medical activities	The Habitat CHP Medical System shall enable crewmembers to prepare the habitat for medical activities.	The Habitat CHP Medical System needs to provide the capability to prepare the Habitat for medical activities. Preparation of the Habitat for medical purposes involves crew activities such as creating appropriate volume for medical tasks (dedicated workstation), placing restraints, providing adequate lighting, noise attenuation, supply of water and oxygen, hand sanitation or washing hands, creating a location that affords privacy and improved cleanliness, enable hands-free interface. Both the Medical and Habitat Systems need to ensure that these activities are adopted.
3	L4-Lunar-MedSys-0006	Access knowledge augmentation	The Habitat CHP Medical System shall access knowledge augmentation data for the performance of medical activities.	The Habitat CHP Medical System needs to provide the capability to access knowledge augmentation data to facilitate on-demand learning when performing complex medical procedures. Knowledge-based technology provides crewmembers with on-demand knowledge (just-in-Time training) on how to perform a medical procedure. Knowledge augmentation baseline data present in the medical system database of information at the start of the mission, becomes enhanced through the mission with data acquired during the mission, and additions to the system from the Ground CHP Medical System.
4	L4-Lunar-MedSys-0007	Synthesize health data	The Habitat CHP Medical System shall synthesize health data.	The Habitat CHP Medical System needs to combine health data from multiple sources. For example, caregiver-patient interviews and exams, vital signs, labs, imaging, relevant physical and environmental data from the vehicle, and information and data from the Ground CHP Medical System to support the caregiver in diagnosis and treatment. Health data synthesis should be performed periodically and coordinated with mission planners in the event of an in-flight medical emergency (e. g., heart attack, stroke, uncontrollable bleeding). The types of health data synthesis, including their periodicity, are specified at Level 5.
5	L4-Lunar-MedSys-0017	Conduct screening exam	The Habitat CHP Medical System shall support performance of screening exams.	The Habitat CHP Medical System needs to provide the capability to conduct screening exams. Screening exams performed in planned tasks, such as periodic health examinations, eye examinations, blood and urine testing, and private psychological/medical conferences. These exams are performed to identify deviations from the normal state so that appropriate intervention may be provided, if required. This capability ensures the medical system provides the equipment, tools, and skills needed to conduct screening exams. Types of screening exams are specified at Level 5.
	L4-Lunar-MedSys-0018	Perform physical exam	The Habitat CHP Medical System shall support the performance of physical exams for planned and unplanned medical activities.	The Habitat CHP Medical System needs to provide the capability to perform physical exams. For example, physical exams, collecting objective anatomic data from a patient, sample collection of blood and urine, performed as part of planned activities (e.g., periodic eye exams) and testbed planned activities (e.g., periodic

ExMC SE Process Update – JIRA

- **Project tracking performed in JIRA**
  - Supports Agile approach
  - Assists in managing workload for Sprints
  - System for backlogging tasks
  - Create Dashboards
    - e.g., Track burn down of issues over time



Summary

- **New content coming in 2023 to the ExMC public-facing website**
  - LDLOLS Foundation
- **ExMC SE continues to support the IMPACT project in FY23**
- **ExMC SE continues to evolve with incorporation of new software tools**
  - Cradle and JIRA
- **Updates to the LDLOLS Foundation based on NASA-STD-3001 (Volumes 1, Rev. B and 2, Rev. C) coming in FY23**

- J. Cohen, M. S. Kaetzer, S. Lumpkins, D. Rubin and K. McGuire, "A Model-Based Systems Engineering Journey to Developing a Concept of Operations (ConOps)," 2022 IEEE Aerospace Conference (AERO), 2022, pp. 1-14, doi: 10.1109/AERO53065.2022.9843691.